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MINES IN THE SURF ZONE: A PROPOSED BREACHING CONCEPT

by

Matthew M. Aylward

September, 1994

Thesis Advisor:

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MINES IN THE SURF ZONE: A PROPOSED BREACHING CONCEPT

by

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

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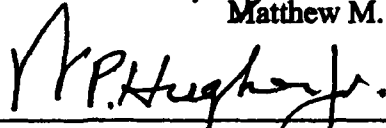
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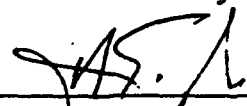


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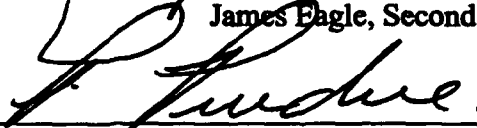
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ABSTRACT

This thesis addresses the threat that mines in the surf zone (ten foot curve to the high water mark) pose to Operational Maneuver From The Sea. Additionally, problems presented by minefields beginning at the high water mark and extending inland are reviewed.

Effectiveness of notional minefields consisting of tilt rod and pressure fused anti-tank mines are modeled as a planar Poisson process. The delivery of the assault echelon (a Marine Expeditionary Force (Forward)) by landing craft is modeled as a simple circular flow process.

Three methods for overcoming the minefields are developed and compared using five measures of effectiveness. A decision criteria for breaching a minefield by bulling through is offered. A breaching concept using fuel air explosives and a unique mine rake are presented.

The thesis concludes that development of the "Blast, Rake, Breach" concept should be pursued.

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EXECUTIVE SUMMARY

The execution of an amphibious assault is perhaps the most complex of all military operations. It involves the movement of personnel and material across the sea and the delivery of these forces to a hostile shore. The commander of an amphibious assault is faced with the difficult task of beginning the operation with zero combat power ashore. The challenge is to deliver sufficient forces to the land before the enemy can react in strength.

While there are a number of enemy actions that can delay or disrupt the sequence of the assault, mines in very shallow water pose a special threat to the Navy-Marine Corps team. Very shallow water is any water less than forty feet in depth; a subset of very shallow water is the surf zone. We define the surf zone as the region from the ten foot curve to the high water mark. The threat of mines in the surf zone is twofold; current mine countermeasure equipment is unsuited for operations in these depths and the delivery systems for laying mines in the surf zone are very unsophisticated. On the one hand, US forces are not well suited to clearing minefields in the surf zone and on the other, any nation that has a truck can create a minefield in the surf zone.

In addition to the general nature of the threat posed by mines in the surf zone, the thesis considers the effect of tide range and beach gradient. These factors are considered important as they affect the size of the task confronting the landing force commander. For example, a beach with flat gradient and small tide range would offer the defender extensive depth for laying minefields and creating obstacles. Conversely, a beach of steep gradient and large tide range offers the defender less room to deploy barriers.

Before developing the methodology used to study this problem, the scope of the thesis, as well as simplifying assumptions, must be understood. The thesis looks at one colored beach used to land a Battalion Landing Team (BLT). This landing team represents roughly one third of the combat power of the Marine

Expeditionary Force (Forward) (MEF(FWD)) considered in this study. The expeditionary force is engaged in a lesser regional conflict (LRC), conducting amphibious operations in support of the theater campaign. The BLT is equipped with Advanced Amphibious Assault Vehicles (AAAV) and Landing Craft, Air Cushion (LCAC). Because the BLT has AAAV's and LCAC's, amphibious assaults conducted over the horizon (OTH) are considered. In this way, the effects of mines in the surf zone on operational maneuver from the sea (OMFTS) are studied. OMFTS embodies the efforts of the Navy-Marine Corps team to face the challenge of littoral warfare.

The minefield constructed for this thesis is very simple. It consists of two types of mines; tilt rod anti-tank mines and pressure fused anti-tank mines. We assume the mines are laid four meters apart, along a one kilometer front. The mine count for the surf zone is 1,000 mines per kilometer, while the minefield on the beach (from the high water mark landward) has a mine count of 2,000 mines per kilometer. These assumptions create a notional minefield with known composition, density and dimensions. Further, using information from open sources, the effect of each mine type (tilt rod or pressure fused) on each assault craft (AAAV or LCAC) is calculated. Calculations show the AAAV is vulnerable to both mines, while the LCAC is only vulnerable to the tilt rod mines. After constructing the notional minefield, the effects of tide range and beach gradient were considered. These factors were used to calculate the distance from the high water mark to the seaward edge of the surf zone minefield as well as the proportion of the minefield exposed at low tide. The proportion of exposure is of importance when considering methods to breach the minefield.

To breach a lane in the minefield, two methods are considered; explosive destruction and physical displacement. While explosives have been used successfully on land for several years, their employment in the surf zone is complicated by the water over the mines. If the explosion occurs on the surface, the blast is attenuated; insufficient force reaches the tilt rod mines. For this reason, the proportion of the minefield exposed at low tide is of interest to commander.

The physical displacement of mines is commonly used on land, usually in the form of plows or rollers mounted on the front of a tank. Obviously, this technique will not work in the surf zone. Separate from the two breaching methods is the idea of breaching by maneuver. To employ this idea, the commander determines that the density of the minefield is low enough to allow assault craft to cross the minefield without further reduction efforts.

With the characteristics of the landing force determined, and the notional minefield constructed, attention is turned towards analysis of breaching concepts. The thesis considers three concepts; Breach by Maneuver (BBM), Helicopter Insert, Breach Seaward (HIBS) and Blast Rake Breach (BRB). As mentioned, BBM is employed when the commander feels the minefield density is low enough that reduction is not needed. HIBS is the current concept for breaching minefields in the surf zone. Helicopters insert a detachment of engineers who then clear a lane through the exposed minefields while a new type of mine rake is pulled by helicopter to breach the mines still covered by water.

Analysis of these methods compares the advantages and disadvantages of each. The models of the minefield are used to determine the level of reduction required to assure mission success while avoiding unacceptable casualties. Finally, the thesis concludes with a recommendation that development of the BRB concept be vigorously pursued.

I. INTRODUCTION

A. PURPOSE

The conduct of an amphibious assault is one of the most complex undertakings in modern warfare. The difficulties are multiplied by the presence of very shallow water (VSW) mines and mines in the surf zone (SZ). The Navy and Marine Corps must develop solutions to this problem in a climate of austere defense budgets, while faced with a high operational tempo and frequent employment in contingency operations. This thesis will develop methods to compare three concepts for overcoming VSW/SZ minefields encountered during amphibious operations.

B. SCOPE

The thesis will consider amphibious operations in a Lesser Regional Conflict (LRC). The thesis will be limited to that portion of the beach from the ten foot curve to the far side of minefields located near the high water mark.

1. Friendly Forces

A Marine Expeditionary Force, Forward (MEF(FWD)), built around a Regimental Landing Team (RLT), is conducting operations in a LRC. The scenario used is taken from the Project Culebra wargame [Ref. 1:p. B-12]. A listing of the order of battle for the MEF(FWD) is found in Appendix A.

2. Concept of Operations

The landing force will employ LCAC's, Advanced Amphibious Assault Vehicles (AAAV) and the OV-22 to conduct the initial assault. These assumptions are made to study the effect of VSW and SZ mines on Over the Horizon (OTH) amphibious assaults.

All landing craft will employ some form of precision navigation equipment (e.g., GPS). This assumption allows inclusion of electronic marking of the battlefield in the concepts considered.

The principle of employing obstacles requires that they be covered by fire or observation. In defending the landing beach, the enemy commander has the option of either meeting the assault echelon (AE) at the water line or laying some distance off the beach in order to conduct a mobile defense. Currently, the Navy-Marine Corps team is striving to revitalize amphibious warfare by imbuing it with the principles of maneuver warfare. When applied at the tactical level, maneuver warfare seeks out gaps in the enemy defenses. Accordingly, this study will assume the assault is planned with these principles in mind; selected landing sites may be lightly defended (they certainly will be under observation), but the bulk of the enemy force will conduct a mobile defense. From this assumption, a logical concern for the CLF is the amount of time required to put some level of combat power ashore. The traditional mark has been combat power ashore at H+90 minutes. Though somewhat arbitrary, this milestone is suitable for the purpose of this study. The reader should recall these points when reviewing the Measures of Effectiveness (MOE) detailed in later chapters.

Task units of the Amphibious Task Force (ATF) will clear from the ten foot curve seaward, as part of supporting operations. Although beyond the scope of this study, deception operations or covert mine clearing would certainly affect the reaction time afforded the enemy.

C. BACKGROUND

The United States Navy, in conjunction with the United States Marine Corps, is turning its attention from the problems of open ocean warfare to the unique challenges presented by "...joint operations conducted from the sea." [Ref. 2:p. 1]. This new focus on operations conducted near the land comes under the heading of littoral warfare. As discussed in the White Paper, "...From The Sea", littoral warfare "...poses varying technical and tactical challenges to Naval Forces." [Ref. 2:p. 4]. The White Paper goes on to detail the challenges facing amphibious operations:

Some littoral threats--specifically mines, sea skimming cruise missiles and tactical ballistic missiles--tax the capabilities of our current systems and force structure. Mastery of the littoral should not be presumed [Ref. 2:p. 4].

Conducting operations in littoral warfare, "...requires a corresponding shift of emphasis toward accelerating the adaptation of existing forces to counter littoral threats." [Ref. 2:p. 5]. Instead of fighting a large fleet action at sea, the Naval Service must now develop doctrine "...ensuring effective transition from open ocean to littoral areas, and from sea to land and back, to accomplish the full range of potential missions" [Ref. 2:p. 6].

1. Operational Maneuver From the Sea (OMFTS)

As discussed above, the White Paper "...From the Sea" shifts the focus of Navy tactical thought from open ocean warfare to the problems presented by littoral warfare. In a similar vein, OMFTS moves Marine Corps tactical thought away from the amphibious campaigns of the Central Pacific (1943-45). While these campaigns embodied maneuver on the strategic level, in tactical execution they were often attrition warfare slugging matches, without latitude for maneuver (e.g., Tarawa and Iwo Jima). Such assaults are not acceptable now, neither to the nation nor to the personnel who would conduct them. The situation requires a new conceptual approach that acknowledges "...structural intolerance of attrition and societal demands for inexpensive victory" [Ref. 3:p. 4]. The concept of OMFTS "Regards forcible entry as a National requirement" [Ref. 3:p. 1], and describes it as "...a single seamless operation extending from a secure sea base across a hostile shore to dominate...enemy center of gravity" [Ref. 3:p. 2]. Further, the Marine Corps holds that OMFTS is "...the application of maneuver warfare principles to the maritime portion of a theater campaign..." [Ref. 3:p. 1].

In maneuver warfare, the focus is on the enemy, not on specific pieces of terrain: "The objective of OFMTS is not seizure of the beach, but the rapid accomplishment of a campaign objective" [Ref. 3:p. 5]. The commander seeks to identify the enemy center of gravity, whether this center is political, economic, cultural or military in nature. Communicating his/her wishes through the commander's intent, the CLF assigns missions

to subordinates. The manner of execution of these missions is at the discretion of the subordinate. As each level understands the commander's intent two levels up, opportunities for exploitation are seized. The attacks are conducted to "...break the cohesion and integration of enemy defenses while avoiding attrition oriented attacks" [Ref. 3:p. 5].

Maneuver warfare is often described as "going where the enemy isn't". However, this is wide of the mark: "An operational concept of avoiding all opposition is neither imaginative nor credible, and it will not support our strategy" [Ref. 3:p. 4]. Rather, the Navy-Marine Corps team must retain the ability to fulfill "...the requirement to strike at the heart of an invader or violent outlaw requires unquestioned ability to power ashore" [Ref. 3:p. 3].

2. Maneuver Warfare and Tempo

The key to understanding maneuver warfare is grasping the idea of operational tempo. This term relates the speed at which one combatant can carry out assigned missions to the speed at which the opponent executes missions. A useful mental construct for this concept is the Boyd Cycle. Developed by Colonel John Boyd, USAF (Ret.), it is also known as the OODA (Observation, Orientation, Decision, Action) Cycle. This theory holds that a commander must execute these four steps each time action is initiated. If one commander can execute the cycle faster than the opponent an advantage is gained. The enemy is faced with a deteriorating situation and the rate of deterioration is ever increasing. In the mind of the enemy commander, control of the situation is lost and defeat is imminent [Ref. 4:p. 137]. Since the side with faster operational tempo can execute missions and adapt to changing situations faster than the enemy, a great advantage accrues. This advantage should not be regarded lightly, for "...land battles seem to be largely won or lost in the minds of opposing commanders at...tactical and operational levels" [Ref. 4:p. 47].

By framing the initial discussion of maneuver warfare in terms of a mental process (OODA Loop), the reader may come to understand that maneuver means more than just timely movement on the battlefield. It is also necessary to consider the physical

aspects of maneuver warfare. Related to operational tempo is the concept of operational mobility, defined as "...the ability to move fast over considerable distances (100-300 miles)...and arrive fit to fight" [Ref. 4:p. 42]. Maneuver warfare also speaks of surfaces and gaps; the physical interpretation is the manner in which the enemy holds the ground. A surface would be a stretch of terrain the enemy holds by occupation or controls by fire. A gap corresponds to a discontinuity in the enemy's defense. In maneuver warfare, the commander seeks to guide the Schwerpunkt, or main effort, through a gap towards the center of gravity.

OMFTS uses the sea as a highway to conduct maneuver warfare over the shore. "It is maneuver at sea which makes maneuver from the sea so decisive..." and thus "...provides the real battlefield advantage to the amphibiously projected Marine Air Ground Task Force" [Ref. 3:p. 3].

3. OMFTS As a Two Stage Movement

In the amphibious campaigns of World War II, the ships of the Amphibious Task Force (ATF) steamed close ashore to the landing beaches before launching the AE. Consider how such movement would appear on a chart; the strategic maneuver is denoted by the arrow connecting the port of embarkation to the landing beaches. The tip of the arrow terminates close to shore; it marks the line of departure for assault craft as they make the final run to the beach.

In contrast, the lines on a chart noting an ATF conducting OMFTS would not terminate as an arrow; rather, the terminus might appear like a fan. This reflects the two stage movement of OMFTS. The ATF closes with landing beaches, but remains over the horizon. The distance off-shore is from 20 to 30 miles, not much more than the distance an AAV can cover in a one hour swim. By launching an OTH assault, the CATF/CLF confound the enemy's defensive preparations. Assuming there are a number of equally attractive penetration points along a coast, the enemy is unable to determine which beach will be selected until the AE is actually ashore. These ideas are best expressed graphically; see Figure 1.

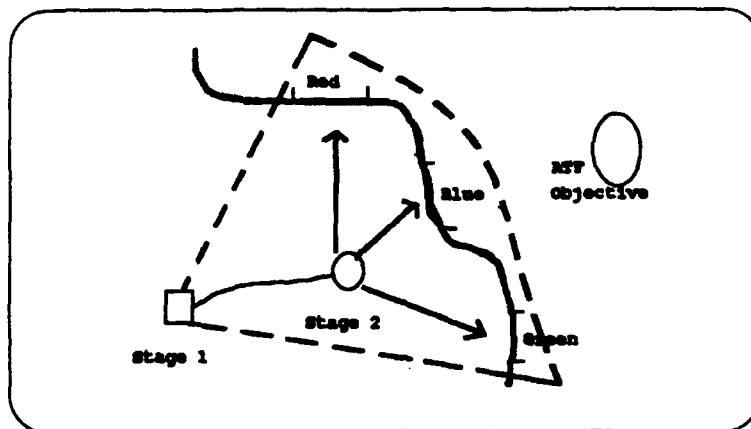


Figure 1. OMFTS as a Two Stage Movement.

In Figure 1, Stage 1 represents the general location on the ATF shipping. It is over the horizon, 20 to 30 miles off the beach. Stage 2 represents the possible paths the AE can follow; the assault could come over any of the colored beaches. The arc denoted by the dashed line marks the section of coast vulnerable to an OMFTS assault. In the case illustrated above, with the ATF 25 miles off shore, and the arc subtending 90°, the enemy commander must defend almost 40 miles of coastline. Also note, the ATF has the advantage of interior lines of communication within the dashed arc.

There are several considerations that must be weighed when coordinating an OTH assault. As the ATF moves farther off shore, greater protection from shore based sensors and weapons is afforded. The threat of mines is greatly diminished with more water under the keel. Further, the defensive problem of the enemy is increased as more coastline falls within the operating fan of the ATF. However, moving too far off shore makes the swim time for the AAV unacceptably long; operating endurance on the beach is affected and the physical condition of the Marines is degraded. Also, with greater distance, the cycle time for the LCAC from ATF to CLZ and back grows excessive.

4. Current MCM Capabilities

As noted, the Navy-Marine Corps team is working to improve its ability to conduct littoral warfare, especially power projection through amphibious assault, by recasting doctrine. However, there remain several problems that must be addressed through changes to tactics, techniques or equipment. One such problem is that of mines in VSW and in the SZ. In order that the promise of operational tempo offered by OMFTS be realized, new capabilities must be developed:

"Viable mine reconnaissance and in stride clearance capabilities will be critical to success in future amphibious operations" [Ref. 3:p. 12].

To appreciate the effort required in developing these capabilities, the reader must understand the capabilities and limitations of current mine countermeasure forces. To begin, let in stride clearance mean that the mine problem is handled in ways "...that allow amphibious forces to launch when and where they had planned...their speed of advance no way impeded by a mine threat..." [Ref. 5:p. 59]. According to Lee M. Hunt, in the April 1994 issue of Proceedings, the current surface and airborne mine countermeasures (MCM) forces can clear mines in to water depths as shallow as 10 to 15 feet [Ref. 5:p. 60]. To be sure, additional equipment, primarily C4 I, Inverse Synthetic Aperture Radar and GPS must be fitted to current platforms. Further, the relationship between the MCM forces and other fleet elements must be altered to reflect the world class threat posed by mines. Within the MCM community, how resources are allocated to intelligence and surveillance must be adjusted. A very useful model for this adjustment is contained in a paper by George W. Conner, Mark A. Ehlers and Kneale T. Marshall: Countering Short Range Ballistic Missiles [Ref. 6].

While current MCM forces can be modified to handle the threat of mines from the 10 foot curve seaward, for the SZ and the beach "...there is no acceptable procedure for clearing mines..." [Ref. 5:p. 60]. The lack of an acceptable procedure and the absence of a methodology to assess alternative solutions forms the basis of this thesis.

5. Current Countermine Concept Development

The Marine Corps Combat Development Command (MCCDC) at Quantico, Virginia is responsible for developing new methods of warfighting. Efforts regarding developments in littoral warfare are embodied by various projects. Part of this effort is represented by the Culebra Project, a series of wargames and analytical studies designed to bring new vigor to amphibious warfare.

Another program at MCCDC is the Advanced Concept Test Demonstration (ACTD). This Joint MCM study will "...integrate existing capabilities and ongoing programs...currently funded into a cohesive and synchronized effort" [Ref. 7:p. 1]. The ACTD is a multi-year program, combining actual exercises with distributed interactive simulations to demonstrate the capability to "...conduct seamless amphibious MCM operations during Joint Naval-Land combat operations" [Ref. 8:p. 3]. An important point made by the brief on ACTD is the recognition that there is no silver bullet. A tool box of tactics and techniques must be developed to overcome the threat of mines in VSW and the SZ [Ref. 8:p. 22].

At the Mine Warfare Command, improvements to MCM capabilities are pursued in several projects. Kits that give the LCAC the ability to conduct MCM missions are a near-term, high priority program. There are also efforts to develop remotely operated vehicles with a fiber optic cable tether, autonomous underwater vehicles and unmanned air cushion mine sweepers. However, these latter programs have uncertain funding futures [Ref. 9]. During a briefing by Captain Craig Sackett USN, of the Mine Warfare Command, a realistic appraisal of near term (zero to ten years) capabilities was offered. In this brief the point was again made that no capability exists to clear mines in stride between the 10 foot curve and the high water mark. Exercises testing the near term concept (i.e., a helo assault seizes a beachhead, then engineers clear a lane seaward) showed it to be difficult to execute. The brief concludes that more work is needed and additional tactics will have to be developed [Ref. 10].

This discussion of current initiatives leads to the conclusion that current systems and tactics can be adapted to reduce the risk of mines from the 10 foot curve seaward.

However, mines in the surf zone could be the real show stopper in an amphibious assault. This thesis will approach the challenge of such mines: "The risk that is not eliminated by improved capabilities is confronted with imagination and boldness..." [Ref. 3:p. 7].

II. NATURE OF THE PROBLEM

A. PROJECTED THREAT

1. Likelihood of Minefields

When planning an OMFTS, the prudent commander will assume that minefields will be encountered, even in the absence of intelligence, because shallow water mines and beach mines are becoming ubiquitous. Mines offer an extremely cost effective way to counter the threat of amphibious assaults. Also, the nations of the former USSR and the Warsaw Pact are short of hard currency. Selling their stockpiles of anti-invasion mines is one way to quickly generate income. Finally, potential adversaries have noted the difficulties mines caused the US Navy during the Kuwaiti tanker re-flagging operations, as well as the effect of Iraqi mines on the Navy-Marine Corps team during Operation Desert Storm.

2. Time, OMFTS and Minefields

Successful implementation of an OMFTS requires that minefields be reduced expeditiously. The current standard is six hours, with the operation starting four hours before BMNT [Ref. 10]. A commander executing an OMFTS cannot tolerate another Wosan harbor; "...unlike past amphibious operations, we will not concede tactical surprise and will take actions to deny the enemy early warning..." [Ref. 11: slide 10]. Further, as the ability of the Navy-Marine Corps team to exploit the advantages of OMFTS increases, the time available for pre-assault breaching will decrease and may be eliminated [Ref. 12:p. 10-11]. Thus, OMFTS drives the requirement to develop in-stride breaching. Mines in the SZ are not easily located by current sensors, especially mines that bury themselves in the bottom. Additionally, these mines tend to be smaller and their density greater. If the clearing technique locates and destroys mines one at a time, this greater density increases the amount of time required to clear the mines.

The presence, or suspected presence, of minefields will weigh heavily on the CATF/CLF as they plan the OMFTS. Maintaining surprise and operational mobility could become mutually exclusive goals. Minefields limit the options available to the commander; if the ATF does not have the ability to overcome them, OMFTS is not possible.

3. Effect of Mines on Assault Craft

The LCAC, though it rides on a cushion of air, still transmits a pressure footprint and a magnetic signature into the water. However, when the mine detonates more than 30 feet below the surface, the craft's speed protects it from blast damage by outrunning the plume of the mine. This protection is provided. If detonation occurs at shallower depths, the plume broaches the surface before the LCAC can move a safe distance and catastrophic damage occurs. This means the LCAC is vulnerable to anti-landing influence and tilt rod mines in the SZ and on the beach. Based on open source information, anti-tank mines fused by the pressure or magnetic signature of passing vehicles are considered. This study assumes that anti-tank mines do not pose a threat to the LCAC on cushion. Finally, we assume the design of the LCAC skirts is sufficiently robust to withstand the blast of anti-personnel mines.

The AAV, as a displacement hull craft, sends a pressure and magnetic footprint into the surrounding water. Its speed in the water (top speed is 25 knots) does not allow it to outrun the plume of a bottom moored mine. The craft has a draft of six feet with the potential to fuse all of the mines discussed above, particularly the anti-tank mines. Even if the AAV does not suffer a catastrophic kill from an anti-tank mine, it will probably suffer a mobility kill from damage to its tracks. However, the hull and running gear are able to withstand the blast from anti-personnel mines.

The other assault craft carried by the ships of the ATF (e.g., LCU) are all displacement hulls. They are vulnerable to the entire range of mines.

4. The Typical Minefield

Though mines can be laid in many patterns, with varying density, a typical pattern for the anti-invasion mine threat is pictured in Figure 2, below:

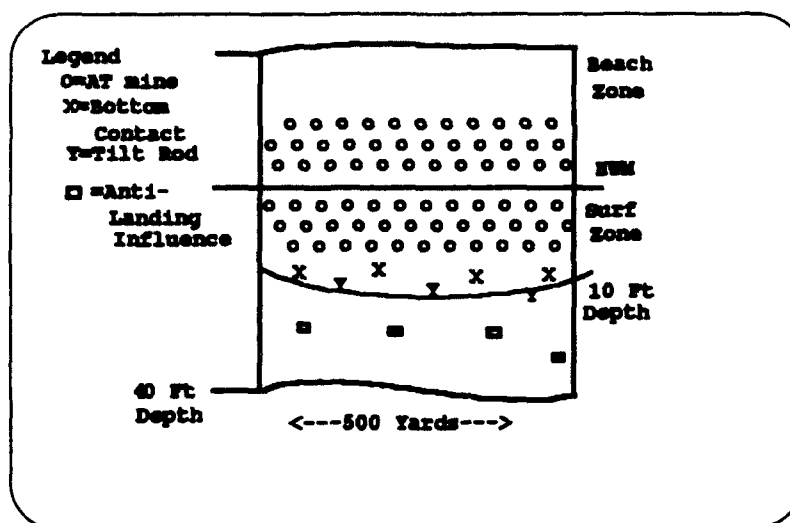


Figure 2. Anti-Invasion Mine Threat.

Minefields of this pattern are very easy to establish. They require minimal technology for the mine delivery system (e.g., they can be laid from a truck at low tide).

B. SYSTEM DESIGN OBJECTIVES

The ideal MCM system will be simple and cheap, yet able to ensure mission success while addressing the concerns detailed in the section below. In particular, the Marine Corps wishes to mount the MCM system on the AAV, thus ensuring the breaching force arrives at the same time as the AE. Such a system would also eliminate the need for additional vehicles [Ref. 11: slide 13].

1. Areas of Concern

Any candidate system must have minimal impact on the lift requirements of the MAGTF. As space onboard amphibious shipping is already at a premium, the footprint, cube and weight penalties of a new system will be weighed carefully against the benefits offered by the system.

Although budget forecasting is very difficult, it is reasonable to assume that current budget trends will continue. For MCM systems, this means that high risk approaches are ill advised. Rather, systems must be developed using proven technology or off the shelf items.

Additionally, there is the problem of diversion of critical assets. Since new MCM systems have to satisfy the foregoing concerns, an obvious approach would develop MCM capability as an add on kit for a system currently fielded. While this is a prudent course, such development must not overcommit critical mobility assets. For example, the Mine Warfare Command is fielding kits for the LCAC. These kits give the LCAC a MCM capability; when installed, the LCAC is designated a MCAC. However, a MCAC is unable to perform the LCAC mission simultaneously. At some point in the amphibious assault this could create a shortfall in landing craft.

With the heavy emphasis OMFTS places on operational tempo and surprise, any system must be designed with these tactical realities in mind. It is of little use for the ATF to have a MCM that is 100% effective, if it gives the enemy sufficient time to react strongly.

C. VARIABLES

1. Tide Conditions

A major difficulty with mines in the SZ is the inability of current sensors to detect their presence. This is due to the attenuating affects of the water and surf. In the near term, the most effective surveillance tools for this problem are visual techniques. Their effectiveness is increased if some means of cueing is available. Mines are often laid on and among anti-boat obstacles. These obstacles are uncovered to varying degrees during low tide. The range of the tide will impact on visual cueing and thus on the probability of detection.

One current technique for overcoming minefields on land relies on explosives. Charges create an over pressure to fuse anti-tank mines or destroy the mines by sympathetic detonation. For this technique to work on mines in the SZ, the problem of

getting the explosive force transmitted to the mines must be overcome. The range of the tide will have an effect on this technique.

2. Beach Gradient

This topic relates to the extent of the minefield and any obstacles present. A short, steep beach will not offer the defender much room to lay mines. Conversely, a flat beach will allow for extensive mining. Therefore, the beach gradient directly affects the work load on the MCM effort and the danger to the AE.

D. MEASURES OF EFFECTIVENESS

1. MOE 1

Time required to clear a given number of lanes of a given width. This MOE is useful for discriminating between systems when considering various landing tactics. For example, the CLF may decide to land at multiple beaches; in this case MOE 1 would favor the most flexible system.

2. MOE 2

Time required to land the AE, including clearance time. As a measure of performance for this MOE, the probability that the number of round trips performed by each LCAC exceeds some minimum level is calculated. If necessary, the losses suffered by the assault craft can be used for further discrimination. A system that creates boat lanes in a short period of time but leaves many mines for the assault craft is of little use. This MOE will screen out such systems.

3. MOE 3

Reaction time afforded to the enemy. This MOE will measure the amount of time that passes between the creation of the boat lanes and the beginning of the landing operation. This MOE is somewhat subjective, in that an evaluation must be made regarding the warning given the enemy. For example, a system may create a boat lane by delivering an explosive charge. If this charge is detonated during strikes on beach installations, the enemy may not notice and therefore not receive any hint that a landing is imminent. MOE 3 is also scenario dependent. The breadth of front defended and the

effectiveness of deception operations become important in estimating enemy reaction time. The reader can see how changing the scenario would affect the outcome of MOE 3.

4. MOE 4

Combat power ashore at H+90 minutes. The arbitrary nature of this MOE has been acknowledged, but it is still a useful measure to gauge the effect of a MCM system on landing the AE.

5. MOE 5

The cost to conduct the OMFTS; based on the expected value of a random variable that counts losses of LCACs. The expected value is converted to a dollar figure by using an average unit cost in FY-94 dollars. This MOE focuses on LCAC's for two reasons; their high unit cost and their impact on a successful landing by the AE.

6. Use of MOE's in Analysis

This thesis will use all five MOE's listed when comparing breaching concepts. The data developed to measure all of these MOE's is affected to some degree by the scenario used. The measures are especially sensitive to the mine threat encountered.

A complete assessment of the costs associated with an OMFTS must consider all losses. The loss of an aircraft, either fixed wing or helicopter, has a major impact on the total cost of the OMFTS. However, this thesis considers only the problems presented by minefields. Minefields have an indirect impact on aircraft; only to the extent that the MCM mission exposes them to enemy anti-aircraft (AA) systems. This thesis does not develop any models of the enemy AA; hence aircraft losses are not included in the cost of an OMFTS. The next section describes three breaching concepts considered in this thesis.

E. BREACHING CONCEPTS

1. Breaching Versus Clearing

Although these two terms are often used interchangeably, they have distinct meanings. This thesis is concerned with breaching concepts; the reader must understand what breaching means.

Breaching is a combat operation of making a safe lane for armored vehicles to go through a minefield; clearing is an uncontested operation of removing or destroying all the mines in the field [Ref. 13:p. 1].

2. Breaching By Maneuver (BBM)

As noted, breaching is a very different concept from clearing. In choosing to employ BBM, the risk of losing personnel and equipment to mines is weighed against the cost of accepting the operational restrictions imposed by the minefield.

The Navy and Marine Corps look at breaching from very different perspectives. The CLF will accept the loss of a few mobility assets to gain maneuver room. The CATF, however, must contemplate the loss of high value assets (e.g., LCACs) against the outcome of accepting denial of landing areas [Ref. 14:p. 4].

Before proclaiming "Damn the torpedoes, full speed ahead!" the CATF and CLF must decide if the risk of bulling through an unreduced minefield is worth the cost. Consideration of the decision criteria developed from model analysis in Chapter IV will assist in this process.

3. Helicopter Insert, Breach Seaward (HIBS)

HIBS is a second breaching concept, utilizing a helo-borne force to execute a vertical envelopment. The objective is located on the far side of the beach minefield. While the infantry establishes blocking positions, engineer elements breach a lane seaward. Once the lane is safe, assault craft (LCAC, AAV) land the remainder of the AE.

4. Blast, Rake, Breach (BRB)

The third method is BRB. In the BRB concept, explosives, delivered by air, are used to create a lane in the minefields not covered by water. A rake, or rakes, pulled by helicopter(s), is used to breach the mines in the surf zone. AAV's pass through this breach and begin prosecuting the OMFTS. Engineer elements, landing by AAV, then use the rake, deposited by the helicopter on the far side of the beach minefield, to expand the beach lane. The engineers use their AAV's to pull the rake(s). Once the beach lane is expanded to the required 45 meters, LCAC's are brought ashore.

BRB is a refinement of an idea put forth by a MITRE Corporation study [Ref. 15]. The key to BRB is the Anti-Snag Plowing System. A description of the plow, taken from the MITRE Corporation study, is found at Appendix B.

Using explosives to breach minefields is a common technique. The Army's Ballistic Research Laboratory has developed a model, [Ref. 13], of fuel air explosives (FAE) as a breaching tool. Their model gives the commander a planning tool to calculate the level of effort required to attain a given level of breaching. Accordingly, this technique is incorporated in BRB.

III. EVALUATION MODELS AND DATA

A. THE ASSAULT ECHELON OF THE MEF (FWD)

Landing the Assault Echelon (AE) of the MEF (FWD) takes place over colored landing beaches. Usually one Battalion Landing Team (BLT) is assigned to a landing beach. A BLT represents approximately one third of the combat power of the MEF (FWD) in the scenario used by this thesis. Figure 3, Colored Beach Schematic, is taken from the brief by Captain Sackett USN [Ref. 10].

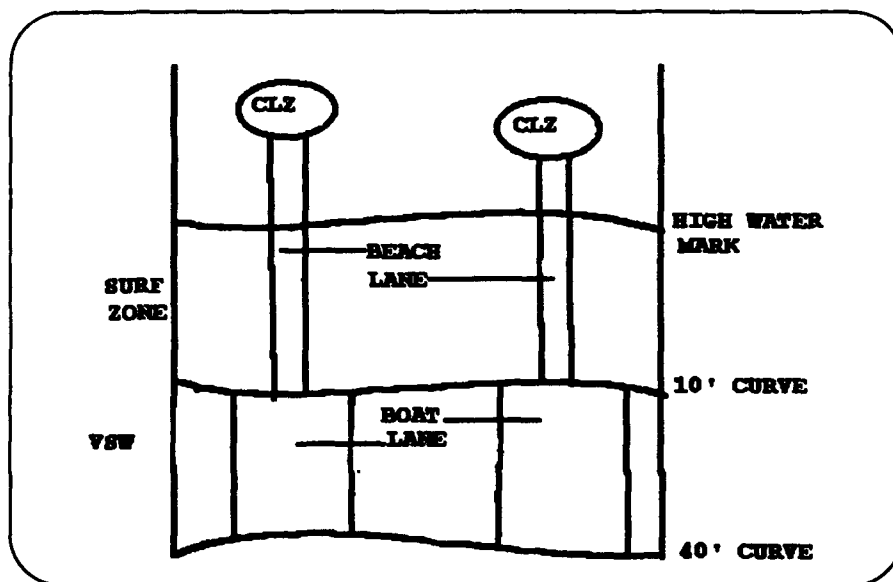


Figure 3. Colored Beach Schematic.

To land the AE, the ATF has 30 LCAC's and 36 AAV's. The thesis assumes landing the AE will require 90 LCAC loads. This assumption is based on the lift capacity of the LCAC and the Task Organization of the MEF (FWD). Consider one colored beach; a single BLT will land here, using ten LCAC's and thirteen AAV's to move the AE

ashore. The number of LCAC loads required is taken to be 30 (i.e., one third of the 90 needed by the MEF (FWD)).

B. THE MINEFIELD

1. Composition and Density

The composition of the minefield will vary with the opponent. Density is inversely proportional to depth. For this thesis, worst case densities are assumed. Figure 4, Notional Beach Profile, notes these densities and lists typical mines used in the SZ and on the beach.

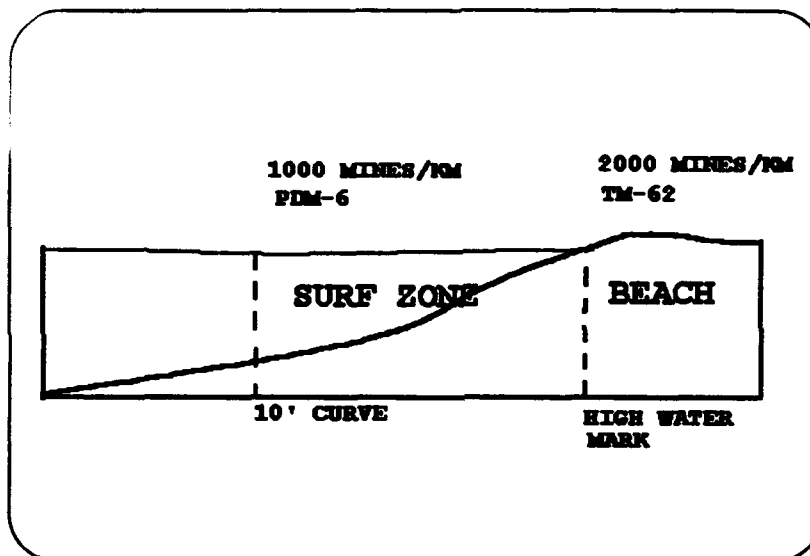


Figure 4. Notional Beach Profile.

2. Depth of Minefields

Assume that mines are laid four meters apart, the minimum distance that prevents sympathetic detonation. For a count of 1000 mines/kilometer, this gives four rows with 250 mines per row. Such a minefield would be 1000 meters wide by 16 meters deep; with a density of 0.0625 mines/square meter. In a similar manner, 2000

mines/kilometer results in a minefield 1000 meters by 32 meters and a density of 0.0625 mines/square meter.

Table 1. Minefield Characteristics

	Surf Zone	Beach
Count/KM	1,000	2,000
Depth (m)	16	32
Density	0.0625	0.0625

3. Traversing the Minefield

The mines are positioned in each field to form a homogeneous Poisson process with mine density r_m (mines/meter²). This implies that the distribution of mines in any subset of the minefield is Poisson with mean = $(r_m) \times (\text{Area})$. Further, the number of mines in disjoint areas are independent random variables [Ref. 16:p. 2].

Assume the vehicles (LCAC or AAV) travel through the minefield in column and let the random variable D equal the number of vehicles destroyed trying to traverse. Then D has the distribution:

$$P[D=d] = [\text{Exp}(-r_m \cdot A_i)] [r_m \cdot A_i]^d / d!$$

$$A_i = (\text{vehicle actuation width}) \cdot (\text{length of breach})$$

C. THE CIRCULATION MODEL

1. Flow

During the assault, personnel and material must flow to the beach. That portion of the effort delivered by air avoids the mines in the SZ and on the beach, while the AAV's must traverse the minefields only once on their way to subsequent operations ashore. The LCAC's, however, must circulate between the beach and the ships of the ATF. This model is suggested by Conner et. al., [Ref. 6:p. 6-9].

2. Model

For the LCAC, a successful cycle is defined as surviving the transit of the minefields and the delivery of its load. The cycle begins at the ATF shipping. It then follows that the first cycle is defined as the transit from the ships to the beach. All subsequent cycles include the round trip from ship to beach and back to ship.

Let the random variable C_i count the number of successful cycles by the i^{th} LCAC. In Figure 5 below, probabilities are defined as follows:

$$Q_A = P[\text{transit fm ATF to CLZ}] = (1-p_1)(1-p_2)(1-p_3)$$

$$Q_B = P[\text{transit fm CLZ to ATF}] = (1-p_4)(1-p_5)(1-p_6)$$

where $P_i = P[\text{LCAC strikes a mine in zone } i] \quad i = 1, 2, 3, \dots, 6$

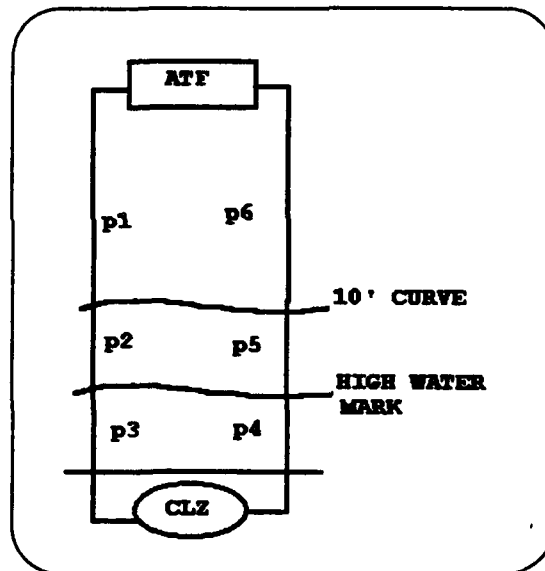


Figure 5. Circulation Model.

3. Distribution of C_i

If the i th LCAC is sunk on the first cycle, it delivers no cargo. If it survives the first cycle, it will continue to deliver loads until the assault is complete or it is sunk. Then C_i has the distribution:

$$P[C_i = n] = 1 - Q_A \quad n = 0$$

$$P[C_i = n] = Q_A(Q_A Q_B)^{n-1}(1 - Q_A Q_B) \quad n = 1, 2, 3, \dots$$

$$E[C_i] = Q_A / (1 - Q_A Q_B)$$

4. Total Loads Delivered

The total number of loads delivered during the assault is the random variable, TL. For TL:

$$TL = \sum_i C_i \quad i = 1, 2, \dots, n$$

$$E[TL] = nE[C_i]$$

where n = number of LCAC's available

D. THE INTERACTION OF TIDE AND GRADIENT

1. Beach Gradient

Though a crude way to classify beaches, [Ref. 17:p. 92], the following criteria is provided:

Table 2. Beach Gradient

Slope	Characterization
1:33	Steep
1:44	Intermediate
1:66	Flat

2. Tide

The range of the tide on a beach depends on many factors. This range can play a significant role in planning amphibious operations. For purpose of analysis, a sample of

tidal ranges was taken from literature [Ref. 18]. Using the fact that a tidal range greater than 15 feet is rarely seen, [Ref. 19:p. 13], the classifications in Table 3 are established: all entries are in meters.

Table 3. Tidal Range

Range	Characterization
0.34	Low
2.47	Medium
4.58	High

3. Interaction

The characteristic gradient and tidal range for the notional beach interact to expose varying amounts of beach at low tide. The entries in Table 4, below, indicate the amount of beach exposed. The distance is from the High Water Mark (HWM) to Mean Lower Low Water (MLLW), in meters.

Table 4. Beach Exposure

	Steep	Intermediate	Flat
Low	11.22	14.96	22.44
Medium	81.51	108.68	163.02
High	151.14	201.52	302.28

E. DATA

1. Assault Craft Costs

To develop data for MOE 5, costs for losses incurred during an amphibious assault are compared. Typically costs are listed as averages for a given fiscal year. To allow direct comparison, costs are adjusted for inflation. Entries in Table 5 are in FY-94 dollars [Ref. 20].

Table 5. Estimated Unit Costs

System	\$Million
LCAC	23.3
AAV7-A1	1.14

2. Dimensions of Assault Craft

The model used to analyze the probability of traversing a mine field uses the vehicle's area as a parameter. For the LCAC, this area equals path length times activation width.

For the AAV, two values are given; one for total area and one for track area. The former is used to determine the probability of detonating a tilt rod (TR) mine, while the latter is used to determine the probability of detonating a pressure fused anti-tank (PFAT) mine. Note that throughout this thesis, the dimensions and capacities of the AAV7-A1 (currently in inventory) are used as proxies for the AAV. The information in Table 6 comes from open sources; OH 7-15 for the LCAC, [Ref. 21], and Jane's Armour & Artillery, [Ref. 22], for the AAV7-A1.

Table 6. Dimensions

	LCAC	AAV7-A1
Weight (kilogram)	153,750	23,991
Width (meter)	14.36	3.27
Track (meter)	N/A	1.09
Area (meter ²)	385.71	12.89
Track Area (meter ²)	N/A	4.28
Grnd Pres (kg/cm ²)	0.04	0.56
Draft (meter)	N/A	1.83

3. Minefield Operational Data and Location

For the purpose of analysis, the minefields consist of one of two mine types: TR or PFAT. The TR minefield is located in the SZ while PFAT mines are on the beach. The data in Table 7 is taken from Jane's Military Vehicles & Logistics [Ref. 23].

Table 7. Mine Data

	TR	PFAT
Fuse Action	Rod Deflection	175 Kg pressure
Operating Depth	1 to 5 meters	N/A
Rod Height	1.05 meters	N/A
Area	N/A	779 centimeter ²
Minimum Actuating Pressure	N/A	0.22 Kg/cm ²

The model used in this thesis assumes the seaward edge of the beach minefield parallels the HWM, with successive rows of mines laid landward. The location of mines in the SZ must meet two criteria: (a) respect operating depth (b) at high tide, the tip of the operating rod must be within 1.65 meters of the surface to ensure displacement hull craft are attacked. Figure 6 portrays these criteria:

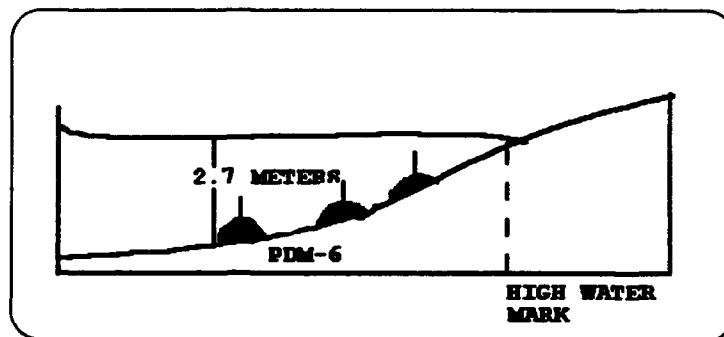


Figure 6. Location of TR Mines.

Thus, the location of the SZ minefield is affected by the tide and beach gradient interaction. Table 8, SZ Minefield Location and Exposure, gives the distance in meters from the HWM to the seaward edge of the minefield. The figure in brackets gives the proportion of the minefield exposed at low tide.

Table 8. SZ Minefield Location and Exposure

	Steep	Intermediate	Flat
Low Tide Range	89.1 [0.0]	118.8 [0.0]	178.2 [0.0]
Med. Tide Range	89.1 [.53]	118.8 [.37]	178.2 [.05]
High Tide Range	89.1 [1.0]	118.8 [1.0]	178.2 [1.0]

4. Recovery Rate

When planning an amphibious assault, installations or systems that have a fast recovery rate are scheduled for attack close to H-Hour. Using typical Warsaw-Pact equipment, Table 9. Minelaying Rates, was established [Ref. 23]. Assuming a delivery rate of 12 mines/minute, the entries reflect the efforts of one vehicle, operating at maximum speed, laying a minefield with a one kilometer front. The last row lists the time required to establish the worst case minefield, where $r_m = 0.0625$ mines/square meter.

Table 9. Minelaying Rates

Action	Speed	Time	Density
Surface Lay	10 KM/Hour	6 Minutes	72 Mines/KM
Bury Mines	3 KM/Hour	20 Minutes	240 Mines/KM
Worst Case r_m	0.72 KM/Hour	1.4 Hours	1000 Mines/KM

IV. ANALYSIS OF BREACHING CONCEPTS

A. MODEL ANALYSIS

1. Introduction

Before proceeding to the analysis of the breaching concepts, insights offered by the circulation and beach models should be considered. These insights are used to develop a breakpoint decision criteria for employing BBM and to assess the level of effort required for BRB.

2. Circulation Model

In this model, the random variable C_i counts the number of cycles by the i^{th} LCAC. The values realized by C_i and the associated value of TL, gauge the success or failure of the landing force. Recall that:

$$E[C_i] = Q_A / (1 - Q_A Q_B)$$

$$\text{Where } Q_A = (1-p1)(1-p2)(1-p3)$$

$$Q_B = (1-p4)(1-p5)(1-p6)$$

For analysis purposes assume:

$$p1=p3=p4=p6=0$$

By this assumption the mines in VSW are assumed cleared and the PFAT mines are treated as before. From this the expression for $E[C_i]$ is simplified:

$$E[C_i] = Q_A / (1 - Q_A^2)$$

As this problem is constructed, ten LCAC's must deliver 30 loads to land the AE. The likelihood of mission success, separate from concern over losses, is gauged by the realized value of C_i . If $C_i > 3$, for all $i, i=1,2,3...10$, the AE will get ashore.

Let the random variable X count the number of LCAC's that survive three or more cycles. Then X -Binomial $(10, P[C_i > 3])$. Define acceptable losses as 20% of the force, or two LCAC's. From this it is a straightforward process to determine the probability of acceptable losses:

$$P[\text{LCAC loss} < 2] = P[X > 8]$$

For analysis, the circulation model is considered with parameters. For various specified values of Q_A , what are the consequences? Table 10 gives the result of such specifications. The required reduction in r_m (from the worst case density of 0.0625 mines/square meter) is calculated from $P[\text{Successful Traverse}] = Q_A = P[D = 0]$.

Table 10. Sensitivity of Model to Q_A

Q_A	0.85	0.90	0.95	0.99
$E[C]$	3.06	4.74	9.74	49.74
$E[TL]$	30.6	47.4	97.4	497.4
$P[C > 3]$	0.4021	0.5715	0.7689	0.9508
$P[\text{LCAC losses} \leq 2]$	0.0127	0.1256	0.5829	0.9889
Reduction of r_m	98.87%	99.27%	99.64%	99.93%

Now the CATF and CLF must determine what actions they can take to ensure mission success (e.g., $P[C_i > 3]$) while reducing the risk of unacceptable losses (e.g., $P[\text{LCAC losses} > 3]$). Before exploring breaching concepts, analysis of the beach model is in order.

3. Beach Model

This model explores the interaction between tide range and beach gradient, as it affects the amphibious assault. Three points made by FMFM 8-3, Advanced Naval Base Defense, are noted [Ref. 24:p. 47]:

Conditions for the installation of underwater obstacles are favorable if beach gradient is flat, bottom firm, the tide range small and the surf mild.

Flat gradients permit extensive use of obstacles, while steep gradients limit their use.

Small tidal range permits continuous concealment of obstacles below the surface while a large tidal range does not.

For the CATF and CLF, the quantity of interest (QOI), is the distance from the seaward side of the SZ minefield to the far side of the beach minefield. This QOI, Path Length, is indicative of the effort required to achieve a breach. As path length increases, two cases can exist. In Case I, the defender has an infinite supply of mines and continues to lay worst case density minefields ($r_m = 0.0625$ mines/square meter) along the entire path length. In Case II the defender has a finite supply of mines intends to lay them along the entire path length. The entries in Table 11 are for the notional beach with the worst case density minefields. All distances are in meters.

Table 11. Path Length

Steep	Intermediate	Flat
121.1	198	210.2

Under the conditions of Case I, r_m is constant while A_i continues to increase. Recall that A_i equals (Craft Width)X(Path Length). From this, Q_A decreases exponentially as a function of A_i . This case is of little interest, as few defenders have an infinite supply of mines.

For Case II, the defender, with a finite supply of mines, must consider the effect of any increases in minefield depth. Assuming the mines are laid equi-distant from one another, increased path length reduces r_m . However, this does not have a proportional effect on the probability of successful transit. This is due to the longer path a vehicle must travel to clear the minefield.

To illustrate this point, consider the values in Table 11. If 32 meters (the depth of the PFAT minefield) is subtracted from each value, the result is the maximum depth

the TR minefield can occupy and still be submerged at high tide. The other values in Table 12 are based on a minefield one kilometer wide, with 1,000 mines/kilometer.

Table 12. Effect of Path Length on r_m

	Steep	Intermediate	Flat
Path Length	89.1 m	166 m	178.2 m
Spacing	9.5 m	13 m	13.4 m
r_m	0.0111	0.0061	0.0056

A qualitative analysis of the beach model leads to the conclusion that the real problem lies somewhere between Case I and Case II. When facing a longer path length, it is reasonable to expect the defender to lay more minefields, of greater depth, along the path. Finally the beach model considers the effect of tide range. For smaller tide ranges, the amount of obstacle exposure decreases. Since current efforts for detecting and breaching obstacles are stymied by water, small tide ranges present more danger to the AE. Figure 7 graphically expresses this interplay.

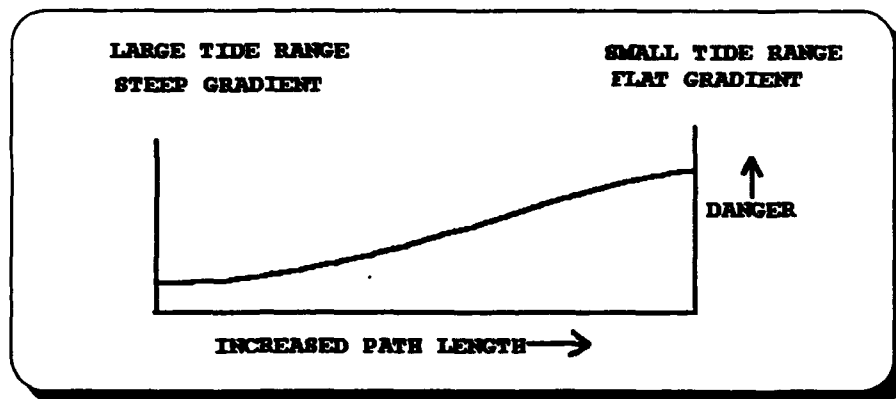


Figure 7. Tide Range-Gradient Interplay.

B. BBM CONCEPT ANALYSIS

1. Minefield Analysis

Recall the planar Poisson model of the minefield. The random variable D counts the number of mines encountered as a vehicle traverses the minefield. The probability distribution of D is:

$$P[D=d] = [\text{Exp}(-r_m * A_i)] * [(r_m * A_i)^d / d!] \quad d = 0, 1, 2, \dots$$

Where r_m = mines/square meter

A_i = Area traversed by vehicle

This model considers two types of mines; TR and PFAT. As discussed previously, A_i is modified to reflect the applicable vehicle width. For a single vehicle traversing the notional minefield, the $P[\text{Successful Traverse}] = P[D=0]$. For each type of mine (TR, PFAT) and vehicle (LCAC, AAV), the $P[D=0]$ is listed in Table 13.

Table 13. $P[\text{Single Vehicle Successful Traverse}]$

	TR	PFAT
LCAC	5.8×10^{-7}	1.0
AAV	0.04	0.12

The entries of Table 13 suggest that BBM of the notional minefield is ill advised. However, a situation akin to Case II of the beach model may arise, creating the opportunity to execute a BBM. To further consider this point, let the random variable S_{LCAC} count the number of LCAC's that successfully execute a BBM in column. For ease of modeling, assume if an assault craft (AAV or LCAC) strikes a mine, it is obliterated and the others in column can proceed along the intended track. For this model there are ten LCAC's to traverse the minefield. The relation between S_{LCAC} and D , the distribution of mines in the path, is expressed as:

$$S_{LCAC} = 10 - D$$

Similarly, the success of AAV's in executing a BBM in column is expressed as:

$$S_{AAV} = 13-D$$

Considering the expected values of these random variables for a traverse of a TR minefield, we have:

$$E[S_{LCAC}] = E[10-D] = 10-E[D]$$

$$E[S_{AAV}] = E[13-D] = 13-E[D]$$

2. Breakpoint Decision Criteria

To develop this criteria, first consider the column of LCAC's transiting a TR minefield in the SZ. Assume the defender is represented by Case II of the beach model. That is, a finite number of mines must be planted along the entire path length, while defending one kilometer of coastline. Depending on the beach gradient, this minefield will vary in depth.

The analysis begins with a desired end state; the required number of deliveries achieved with acceptable losses. From this information, using expected values, the equation is solved for r_m . The value of r_m is used, in turn, to find the exact probability of acceptable losses as well as the mine count for the beach in question. These steps are expressed mathematically:

$$E[S_{LCAC}] = 10 - E[D]$$

$$E[D] = 10 - 8 = 2$$

(recall acceptable losses are < 2)

$$E[D] = 2 = (r_m) * (A_t)$$

$$r_m = 2 / (14.36) * (\text{Path Length})$$

Determining Exact Probability:

$$P[S_{LCAC} > 8] = P[D < 2] = \sum_i P[D = i] \quad i = 0, 1, 2$$

Determining Mine Count:

$$\text{Mine Count} = (r_m) * (\text{Path Length}) * (1,000 \text{ m})$$

Using the steps described above, the tables following were developed. Note, to express the desired end state for the AAV, the model uses:

$$E[S_{AAV}] = 13 - E[D]; E[D] = 3$$

Also, the AAV uses one width (3.27 m) for TR mines and another (1.09 m) for PFAT mines. Finally, assume that the depth for PFAT minefields beyond the HWM is the same as minefields in the SZ.

Table 14. Breakpoint for LCAC: TR mines in SZ

Path Length	r_m	$P[D \leq 2]$	Mine Count
89.1 Meters	.0016	0.6639	143
166 Meters	.0008	0.7018	133
178.2 Meters	.00078	0.6778	139

Table 15. Breakpoint for AAV: TR mines in SZ

Path Length	r_m	$P[D \leq 3]$	Mine Count
89.1 Meters	.0103	0.6470	917
166 Meters	.0055	0.6504	913
178.2 Meters	.0051	0.6535	907

Table 16. Breakpoint for AAV: PFAT mines on Beach

Path Length	r_m	$P[D \leq 3]$	Mine Count
89.1 Meters	.0309	0.6470	2753
166 Meters	.0166	0.6466	2755
178.2 Meters	.0154	0.6492	2752

Determining a decision criteria from the above tables is straightforward in theory, but difficult in execution. For example, the CATF/CLF may decide to execute a BBM if the chances of unacceptable losses is less than 40%. Now the problem becomes one of determining the mine density, which is a function of the mine count, the mine spacing and the dimensions of the minefield. Therefore, making a recommendation to execute a BBM requires accurate, up to date intelligence on the mine threat. Current sensors are limited in their ability to provide such information.

It is important to note the required reduction (86%) of TR mines in the SZ necessary for the LCAC's to execute a BBM. This fact should serve as a cue for focusing intelligence gathering efforts, as LCAC's are a key component of OMFTS.

3. Other Considerations

BBM has two important advantages over HIBS and BRB. First, it offers the best chance for tactical surprise. It offers the defender no warning that an attack is imminent. Second, it does not cause any aircraft (helo or fixed wing) additional exposure to enemy AAA or SAM's.

The drawback to BBM is the critical role rm plays in determining its success. Accurately evaluating rm is an extremely difficult task given the systems currently in use.

Finally, note that BBM does not employ the circulation model. It assumes that lane clearing will follow the breach and initial lodgment ashore.

C. BRB CONCEPT ANALYSIS

1. Minefield Reduction Before Breaching

To breach the TR and PFAT minefields considered in this thesis, two techniques exist: explosive detonation or physical displacement. The advantages and disadvantages of each are summarized below:

Table 17. Minefield Breaching Techniques

	Advantage	Disadvantage
Explosive Detonation	-Standoff distance -Speed of breach	-Cumbersome to bring to bear -Lane less than 100% clear
Physical Displacement	-Defeats all types of mines	-Danger to system -Slow speed of advance

Mines in the SZ present a unique challenge. Neither sea nor land MCM techniques are well suited for this application. Further, the minefield at the HWM is not easily engaged by current land MCM systems; the near side of the minefield (i.e., the SZ)

does not offer the required maneuver space. BRB seeks to meet these challenges by combining both techniques to exploit the advantages of each.

The minefield model offers insight into the value of reducing r_m before attempting a traverse. Table 18 lists the $P[\text{Successful Traverse}]$ by a single vehicle for different levels of reduction to r_m :

Table 18. $P[\text{Successful Traverse}]$ With Reduction

	TR	TR	TR	PFAT	PFAT	PFAT
	$.01 \cdot r_m$	$.1 \cdot r_m$	$.15 \cdot r_m$	$.01 \cdot r_m$	$.1 \cdot r_m$	$.15 \cdot r_m$
LCAC	0.860	0.238	0.116	1.0	1.0	1.0
AAV	0.967	0.721	0.612	0.979	0.808	0.653

The minefield model also gives insight into the trade off between losses and level of reduction effort. Again, assume the commander will accept a 20% loss in each assault craft; equating to losing two LCAC's and three AAV's. The entries in Table 19 list the probabilities that losses will not exceed acceptable limits. This analysis represents the case where each vehicle traverses the minefield once. Return trips by the LCAC's are considered in the circulation model.

Table 19. Trade Off Analysis

	TR	TR	TR	PFAT	PFAT	PFAT
	$.01 \cdot r_m$	$.1 \cdot r_m$	$.15 \cdot r_m$	$.01 \cdot r_m$	$.1 \cdot r_m$	$.15 \cdot r_m$
$P[\text{LCAC loss} \leq 2]$	0.996	0.8259	0.6370	1.0	1.0	1.0
$P[\text{AAV loss} \leq 3]$	0.990	0.9996	0.9984	0.9999	0.9999	0.9996

Throughout the model, an LCAC on cushion passes over PFAT mines without harm. Naturally, should the LCAC go off cushion on a PFAT, damage would result.

2. Pre-Breaching Operations

Employment of any breaching concept requires some prior operations. Detecting the location and extent of the minefield(s) is most important. As a subset, the composition of the obstacle is also required.

Certain anti-landing obstacles must be reduced before BRB can be executed. In particular, anti-boat cruciform obstacles in the SZ will interfere with the rake. However, the very presence of such obstacles acts as a cue for focusing intelligence collection efforts.

3. Blast Action

Explosive destruction of mines works in two ways. The primary action creates an over pressure effect; detonating PFAT and TR mines by actuating their trigger mechanism. Some number of mines are destroyed by the explosives directly.

The BRL report, [Ref. 13], points out that FAE are ideally suited to breach PFAT and TR minefields. An additional benefit of this technique is the minimal disturbance caused to the intended breach lane.

The primary difficulty in using blast action to breach in the SZ is the effect of water coverage. The water over the mines dissipates the blast wave. To be effective, the explosives must be placed hard by the mine prior to detonation.

BRB avoids this problem by the rake in the SZ and the blast on the exposed beach. The amount of explosives required depends on three factors: the path length, the $P[\text{blast clears a segment of path}]$, level of clearance desired.

4. Rake Action

The anti-snap plowing system is fully described in Appendix B. It is constructed of bar steel and chain, using off the shelf items. The inventor makes claims regarding its robustness, [Ref. 13:p. 16], and efficiency [Ref. 13:p. 21]. Further analysis and testing of these claims is recommended.

For this thesis, consider a rake constructed as detailed in Appendix B; Figure 1, but of somewhat greater width. This rake clears an eight meter swath, weighs approximately 8,000 pounds and generates 20,000 pounds of drag when plowing.

5. Mechanics of BRB

Initially the rake, pulled by the helicopter, clears a path through the SZ minefield. It then is pulled up the beach lane to the far side of the beach minefield. At this point the rake is released by the helicopter, for subsequent employment by engineers. Figure 8, BRB Concept, is a graphic portrayal of this sequence.

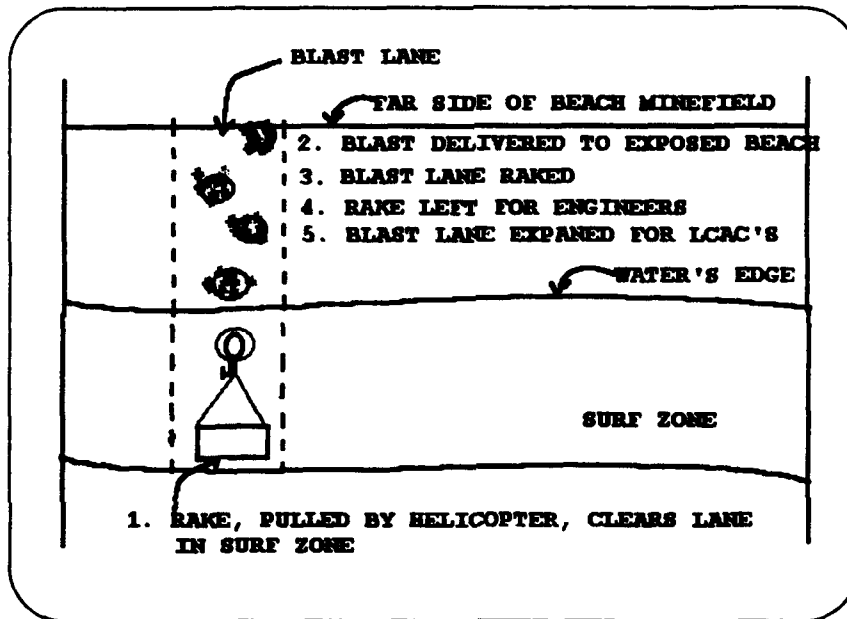


Figure 8. BRB Concept.

The action of the rake in the SZ is vital to the success of BRB. Recall the effect the TR mines have on LCAC's; they are the primary threat to mission success. Additionally, the location of this minefield protects it from explosive detonation: it must be reduced by physical displacement.

6. Other Considerations

BRB depends on local air superiority. While towing the rake, the helicopter is very vulnerable to ground fire. Delivery of the blast action in the BRL report is by AV-8B dropping CBU-72 FAE bombs [Ref. 13:p. 3]. Multiple sorties are required to

ensure r_m has been reduced to a specified level. Each additional sortie puts the crew and aircraft at greater risk. In addition to local air superiority, suppression of enemy air defense must be addressed.

Lane marking should exploit the capabilities of GPS. The use of GPS to disseminate information on minefields, breaches and lanes will assist in maintaining a high operational tempo [Ref. 14:p. 3].

D. CONCEPT COMPARISON

1. Design Objectives and Areas of Concern

Three breaching concepts have been discussed in this thesis. Assuming the decision criteria for selecting BBM or BRB is utilized, it is possible to consider how well each concept meets stated design objectives while addressing specific areas of concern. Table 20 is an assessment of the three systems.

Table 20. Design Objectives

	BBM	HBS	BRB
Simple & Cheap	Yes	Yes	Yes
Mount on AAV?	N/A	No	Not Required
Travel With AE?	Yes	No	Yes
Impact on ATF Lift	None	None	Yes
High Risk Development?	No	No	No
Support Operational Tempo & Surprise?	Yes	No	Yes
Diversion of Critical Assets	No	Yes	Yes

2. Measures of Effectiveness

To determine unequivocally how well each concept satisfies the requirements of the MOE's is beyond the level of this thesis. Making such determinations entails analyzing a large body of data. At this time few data points exist. However, assuming

each concept is employed in the appropriate scenario, some reasonable assessments can be made. Using the models previously discussed, the entries in Table 21 are submitted for consideration. For MOE 5, the expected value of the random variable D is used. Recall that for BBM, $E[D] = 2$ and for BRB, $E[D] = (r_m) * (A_i)$. The value of r_m is obtained from the circulation model under the assumption that $Q_A = 0.95$. To estimate the amount of combat power ashore, assume a 90 minute cycle time for LCAC's. Let the AAV's represent 25% of the combat power while ten LCAC loads are equivalent to 25% of the combat power available to the MEF (FWD).

Table 21. Measures of Effectiveness

	BBM	HBS	BRB
MOE 1: 1 Lane 45 m wide	5 Minutes	6 Hours	15 Minutes
MOE 2: $P[C \geq 3]$	N/A	Can' t Determine	0.7689
MOE 3: Enemy Reaction Time	None	6 Hours	None
MOE 4: Combat Power at H+90	50%	25% (Helo force)	75%
MOE 5: OMFTS Cost(FY-94\$M)	46.6	Can' t Determine	1.2

V. RECOMMENDATIONS

A. CONCLUSIONS

The Blast Rake Breach (BRB) concept offers the promise of a near-term in-stride breaching capability. Not only will BRB support OMFTS, it can be of immediate aid to the conduct of amphibious operations today. Development should commence under the aegis of the ACTD at MCCDC, Quantico, Virginia.

B. CONCEPT DEVELOPMENT

1. The Countermine Concept

No system should be developed for its own sake. Rather, development should flow from an understanding of how it will serve the Navy-Marine Corps team. Understanding how OMFTS and the countermine concept will serve the Navy requires a fundamental shift in the CATF's self perception.

Just as the Commander, Carrier Battle Group and Commander, Air Group think with one mind on the air wing as a power projection tool, so must the CATF and CLF develop a shared outlook. The beach cannot demarcate separate areas of responsibility; the Navy's job goes beyond the simple delivery of the AE. The Marine Corps must learn to exploit maneuver at sea to multiply combat power ashore.

The CATF and CLF together must weigh the MCM effort (e.g., requiring the $Q_A > 0.95$) against the objective of the OMFTS. Minefields exist to create seams and gaps; they put the brakes on operational tempo. The CATF and CLF must not allow this.

2. Before We Go "Once More Unto the Breach"

During the early years of the Strategic Defense Initiative great effort was spent developing ways to intercept Soviet ICBM's in the boost phase. If engagement was successful, the problem of targeting a plethora of MIRV's was avoided. This principle,

shooting the archer, has obvious applications for OMFTS and mine countermeasures. The CATF and CLF must bear it in mind; they must look for opportunities to exploit it.

Short of destroying the mines before emplacement, knowing where they are is the next best thing. Efforts to improve surveillance and reconnaissance capabilities should be pursued.

3. Field Tests

To develop BRB into a useful tactic, several questions must be addressed, principally, the claims made by the inventor for the Anti-Snag Plowing System regarding durability and efficiency. Then, if warranted, practical matters about a helicopter carrying and employing the rake must be explored.

Since BRB also depends on blast action, "A key but unknown measure, $P[\text{Mines cleared in a given stretch}]$..." must be determined [Ref. 13: p. 1]. This can only be accomplished by field firing.

Finally, as any breaching concept will likely have many moving parts, realistic tests in operational conditions will be necessary. The fog of war and friction are not well modeled by current simulations.

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APPENDIX A: TASK ORGANIZATION

1. Forces Assigned

a. Naval Forces

Amphibious Battle Group: 3 LHD'S, 1 LHA, 4 LSD'S, 3 LX'S, 2 LPD'S, 2 LST'S, 1 LPH (MINE), 2 MCM'S, 2 MHC'S, 6 DD'S, 2 FFG'S, BEACH GROUP DET (37 LCAC'S, 4 LCU'S, 6 LCM-8'S), SEAL CO'S+.

Carrier Battle Group: 2 CVN', 2 CG'S, 4 DD'S, 2 DDG'S, 2 FFG'S, 2 AOE'S, 1 SSN

b. Marine Forces: II MEF (fwd) HQ,

Ground Combat Element: INF REGT (REIN): HQ, 4 INF BN'S(REIN), 1 ARTY BN+1 BTRY, 1 AAV CO+1 PLT, 8 LAI PLT'S, 1 TANK CO, 1 ANTI-TANK PLT+1 SECTION, 1 CE CO+, 1 RECON CO+

Air Combat Element: COMPOSITE GROUP: 48 MLR'S, 16 CH-53E'S, 18 AH-1'S, 9 UH-1'S, 20 AV-8B'S

Combat Service Support Element: BSSG: HQ, DET MAINT BN, DET ENGN SPT BN, DET MOTOR TRANSPORT BN, DET MED/DENTAL BN'S, DET LSB, DET SUPPLY BN

APPENDIX B: ANTI-SNAG PLOWING SYSTEM

EXPRESS MAIL NO.: RB402035359

NIL-8762

ANTI-SNAG PLOWING SYSTEM

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BACKGROUND OF THE INVENTION

There currently exists an urgent need to remove hundreds of thousands of mines that have been buried in the desert in the Middle East. The mine-clearing techniques presently in use are expensive and time consuming, as well as dangerous. Tanks with heavy, front-mounted rollers are used to blow up mines, with the rollers having a life expectancy of about two hits. Tanks with front-mounted, V-shaped plows are also used to dig up or detonate buried mines, with the plows having a life expectancy of one hit on each side of the plow. Long line charges are also used in attempts to detonate mines, but these devices do not work well with the sophisticated trigger mechanisms used in modern mines. These mine-clearing techniques are not practical for the larger scale removal required now. The situation is complicated further with crude oil covering large areas of mined land.

Others have attempted to use farmer's harrow devices and/or chains to dig out and clear mines, but these have been unsuccessful because they do not dig adequately, and they are easily blown apart.

There thus is a strong demand for a mine-clearing device that is safe, fast, and relatively inexpensive. There is also a demand for a mine-clearing device that can be used in all types of terrain.

In seeking to design a mine-clearing device suitable for extensive use in the Middle East the present inventor has also designed what turns out to be a very effective plowing system that requires only 1/3 the energy of prior plowing systems for 6" - 10" deep ground penetration. Consequently, this has generated considerable interest among farmers.

Obstructions have always been a problem when plowing - blades are bent or broken, rigid supports are bent, and the like. Thus, whether or not one is clearing mines or farming, there is a need for a plow that is not damaged when the blades snag on buried objects that will not readily move.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a fast, reliable, and inexpensive plow that is suitable for either mine-clearing or farming. The present invention provides an anti-snag plowing system which can be pulled from a safe distance with a helicopter for mine-clearing, or pulled with a tractor for farming.

It is a further object of the present invention to provide a plowing system that uses a modular chain matrix construction that is highly resistant to detonations, and, if damaged, can be easily fixed.

It is still a further object of the present invention to provide a plowing system that comprises a plurality of digging-knife units, each with a set of digging-knives, affixed to the chain matrix in such a way that they will not snag on buried, "immovable" objects. The digging-knives (so called because they resemble bread knives) are specially designed to slice easily through the earth, and to lift buried objects to the surface.

These, and other objects of the invention are realized by using a towing unit such as a tractor or a helicopter to tow a chain matrix that loosely connects digging-knife units and flexible harrow sections so they are towed in tandem. The leading chains in the matrix pull several digging-knife units that form a type of plow. The digging-knife units in turn pull a harrow via the chain matrix, which advantageously overlaps and forms a chain blanket over the harrow so that any mines that detonate in the vicinity of the harrow will only destroy a small section of the harrow and chain matrix. Without the chain blanket's unique pattern and the surprising amount of reinforcement resulting therefrom, the harrow would be lifted and caught in the main force of a large mine explosion, and a substantial portion, if not the entire harrow, would be displaced and/or destroyed. The unique two-layer chain matrix/harrow design of the present invention has been successfully tested over actual minefields in March 1991.

The digging-knife units have an anti-snag feature that is unique to the present invention. When one of the digging-knife units hits a buried "immovable" object the torque (about the point of contact) exerted on the digging-knife unit from the chains pulling it forward is greater than the torque exerted by the chains pulling it backwards (due to the drag of the harrow). This occurs because the drag from the harrow which has a large amount of "give" when pulled more in one place than in others. The chain matrix design exploits this flexibility so that upon hitting a snag the digging-knife unit is momentarily rotated so the digging-knives are tilted to ride over the object. Once past the immovable object the drag from the harrow forces the knives back into the ground. Damage to the digging-knife units from snags is thus advantageously avoided with the unique design of the present invention. In part, this feature is unique because the towing unit must tow both the digging-knife units and the harrow, so not all of the towing force can be used for plowing with the digging-knife units. Thus, the present invention takes advantage of the added pull on the digging-knife units from the harrow to provide a plowing system with an anti-snag feature. If they are damaged from a mine detonation the units are modular, inexpensive, and easy to replace.

The above features of the present invention will be more clearly understood from the following detailed description of the invention with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a plan view of a complete chain matrix with the attached digging-knife units and harrow according to the present invention.

Figure 2 is a schematic of a digging-knife unit in accordance with the present invention.

Figure 3 is a schematic of the harrow drag with reinforcing chains according to present invention.

Figure 4 is a diagram to illustrate the anti-snap mechanism of the plow in accordance with the present invention.

Figure 5 is a plan view of a symmetrical, anti-snap plow according to the present invention.

Figure 6 is a schematic of a reversible digging-knife unit in accordance with the present invention.

Figure 7 is a plan view of an anti-snap plow with electromagnetic or pressure wave detonation triggers on the harrow in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A single-sided embodiment of the present invention is shown in Fig. 1. Anti-snap plow 10 includes digging-knife units 12 and harrow 14, which has a modular construction and a reinforcing blanket of chains 16. Spreader bars 18 and 20, and draw bar 22 are bolted to a chain matrix that includes side chains 24 and reinforcing chains 16. Draw bar 22 has draw bar cables 26 that end in a fastener 28 for attachment to a helicopter or tractor via a tow line. a unique, major feature of this plow system is that is allows "stand-off" minesweeping by mechanical means for the first time, because the helicopter can easily maneuver and tow the chain matrix on the end of a 400' - 800' cable. Ground vehicles may also be used for clearing mines. For instance, two vehicles may tow plow 10 between and behind them if two parallel lanes have already been cleared.

When towed, draw bar 22 pulls on five side chains 24 which are bolted to the front and rear sides of digging-knife units 12. (In operation with a helicopter, the tow cable is long enough to insure draw bar 22 remains close to the ground.) If there are two rows of digging-knife units 12, as shown in Fig. 1, side chains 24 are bolted in series so the rear of the first row pulls the front of the second row. (Optionally, each digging-knife unit 12 may have individual side chains 24, although weight is a consideration when towing with a helicopter. Also, adjacent digging-knife units may share the same side chain, as in Fig. 1, or they may have separate side chains.) Side chains 24 are attached to harrow 14 (may be attached directly, or via front spreader bar 18) so the rear bolt attachment to the second row of digging-knife units 12 pulls harrow 14.

Front spreader bar 18 and rear spreader bar 20 are attached to harrow 14 and chains 16. Chains 16 are patterned to form a reinforcement for harrow 14 that dramatically reduces the damage sustained from a mine detonation. If harrow 14 is not covered with a chain blanket it is lifted and torn apart by the blast. It was found that the unexpected protection provided by chains 16 occurs because the extra reinforcement they provide is sufficient to prevent harrow 14 from being lifted by the explosion. Consequently, most of the energy and momentum from the mine explosion escapes before it can spread through the harrow's loose lattice-like structure, and only local damage is sustained. This may be easily repaired because harrow 14 has a modular construction of 1m x 2m sections. of course, chain blanket 16 is not required for farming.

In a preferred embodiment all chain sections are 3/8", high test schedule 70, and are 16' long. Side chains 24 in the embodiment of Fig. 1 are one chain section long. All chain attachments are made with simple chain loops and bolts so repair is simple.

Draw bar 22 has a 4" diameter, and front spreader 18 and rear spreader 20 are 3" and 4", respectively. All bars are schedule 40. The metal bar have small chain loops or eyelets welded in the locations where they are fastened to the loops at the ends of the chains.

Harrow 14 is made in England by Parmiter & Sons, Inc., and it comes in 1m x 2m sections to form a harrow approximately 15' x 30' for the present invention. The sections fit together with hooks to make a harrow with any desired size. This particular type of harrow is preferred because it has a great deal of flexibility.

Fig. 2 shows a digging-knife unit 12 according to the present invention. Each digging-knife 30 is 1/4" - 3/8" thick by 3" - 4" wide bevel-edge plow steel. Digging-knives 30 are 6" - 12" long, or even longer depending on the soil. They preferably form a 28-30 degree forward angle with the vertical when plowing. Top bracket 32 is 4"x1"x3/8" angle iron, or 5" wide flat bar rolled up slightly to for a streamlined surface for the dirt to flow over. Digging-knives 30 are butt welded on both sides to top bracket 32. Side brackets 34 and back bracket 36 are 3"x3"x1/4" angle iron. Side brackets 34 are 4'-8' long, and top bracket 32 and back 36 are about 40" long in the present embodiment. "Mine-catching" baskets 38 has approximately 3" mesh. Baskets 38 may be used to catch debris that digging-knives 30 turn up, which in tests is virtually everything larger than the preferred 4" spacing between them. If two rows of digging-knife units 12 are used, as in Fig. 1, digging-knives 30 in the second row may be made deeper than the digging-knives in the first row.

A detail of harrow 14 and reinforcing chains 16 is shown in Fig. 3. Chains 16 running lengthwise are spaced the same as side chains 24, or about 40". This facilitates connections along front spreader bar 18. Cross-chains 16 are spaced at 4' - 8' intervals. Harrow 14 is made of 1/2" - 3/4" wire rod bent to form an interlocking pattern with wire ends bent down to from tines 40 that are 2" - 6" long, and spaced about every 8". harrow 14 has a large amount of flexibility due to the loose connections at the joints.

If plow 10 is made as described, with 6" digging-knives and 3" tines, the entire unit weighs about 4000 pounds. A Vertol 107II helicopter was able to pull it at about 10 mph through rocky soil with about 10,000 pounds of towing force. Of this, about 4000 pounds was due to the drag from the harrow. The plow performed superbly, with everything larger than 4" (the spacing between the digging-knives) pulled up, and

there were no broken digging-knives. Imitation mines were also buried at typical depths, and all of these were pulled up.

The anti-snap feature of plow 10 is best understood with reference to Fig. 4. The drag force on digging-knife unit 12 is such that the tension TR on the rear side chains 24 keep side bracket 34 at ground level unless digging-knives 30 strike an obstruction that would be likely to damage digging-knife unit 12 or stop the towing vehicle if there was no anti-snap release mechanism. When a digging-knife unit 12 hits an "immovable" object the tension in side chains 24 towing it forward, τ_F , gives rise to a torque τ_F that wants to rotate it one direction. A reverse torque τ_R , due to the drag tension TR from harrow 14, wants to rotate snagged digging-knife unit 12 in the other direction. However, $\tau_R < \tau_F$ because there is enough elasticity in harrow 14 to allow a portion of the chain matrix to change its configuration as the snagged digging-knife unit 12 passes over the obstruction. The changing configuration adjusts to allow the rear side chains 24 between the snagged digging-knife unit 12 and harrow 14 to move forward more rapidly than the rear side chains of the other digging-knife units. This built-in elasticity prevents TR from ever getting large enough to cause $\tau_R > \tau_F$. Snagged digging-knife unit 12 rotates forward unit 1 digging-knives 30 are tilted forward to pass over the obstruction. (Note that once digging-knife unit 12 passes over the obstruction τ_F vanishes except for the normal plowing torque, and θ immediately returns to zero since τ_R is nonzero, i.e., $\tau_R = L \times TR \times \sin\theta$. This prevents digging-knife unit 12 from rolling all the way over in the forward direction.)

If there is more than one row of digging-knife units 12, and a digging-knife unit in the front row hits an obstruction sufficiently embedded to initiate the anti-snap mechanism, the ensuing rotation advantageously pulls the digging-knives of the digging-knife unit in the second row out of the ground.

Fig. 5 shows a plan view of an anti-snap plow 42 that can be towed in either direction, depending on which side it is on. This is important and convenient for helicopter towing operations because lifting the plow cleans the chain matrix of mines

and other debris. Plow 42 can be lifted, cleaned, and put back down on the other side. The towing cable from the helicopter can then be rapidly changed from one side to the other for towing in the other direction.

Plow 42 has a single row of symmetrical digging-knife units 44 that are offset with respect to their neighbors. If the towing direction is as indicated, the parts identified by the same number in Fig. 1 are the same, and all of the previous discussion pertaining to these parts is applicable here. As drawn, if plow 42 is rotated about an axis parallel with side chains 24 the towing direction is reversed.

Harrows 14 and 46 may be double-sided with tines on top and bottom. Chain blanket 16 is then sandwiched between the top and bottom harrow layers. In this way the ground is harrowed both before and after the digging-knives pass through. They are each preferably made slightly smaller in this embodiment because of weight considerations. Bar 48 serves as an extra spreader bar, and there is a "vestigial" set of draw cables 50 when plow 42 is towed in the direction indicated.

A symmetrical digging-knife unit 44 for plow 42 is shown in Fig. 6. In this case the parts identified by the same number in Fig. 2 are the same, and all of previous discussion pertaining to these parts is applicable here. In symmetrical digging-knife unit 44 the reversed top bracket 50 replaces back bracket 36 in the single-sided embodiment. "Mine-catching" basket 52 is modified to allow reversed digging-knives 48 to serve as the back of the basket. Since the basket mesh only runs along side brackets 34 it does not interfere with the operation of digging-knife unit 44.

An embodiment of the present invention that utilizes harrow 14 as a platform for magnetic or sonic triggering devices is shown in Fig. 7. (Modified anti-snag plow 54 is shown as having two rows of digging-knife unit 12 that are not staggered with respect to their neighbors, and each has individual side chains 24 - this is another configuration in a preferred embodiment.)

Harrow 14 carries triggering devices 56 capable of activating the sophisticated fuses used in modern military mines which are designed to detect a change in the local magnetic field due to an approaching heavy metal object such as a tank, or to

detect ground pressure waves from an approaching military vehicle. Triggering devices 56 may generate either magnetic fields, or sonic waves with electricity supplied from a generator carried on the towing unit.

The devices 56 that are shown in Fig. 7 illustrate an embodiment in which devices 56 are coils of electrical wire powered by electrical cables from the towing vehicle, which carries a generator. Coils 56 generate local high-intensity magnetic fields of any desired frequency. In a preferred embodiment the magnetic fields of adjacent coils alternate in polarity. Harrow 14 forms an ideal ferromagnetic conduit so the tips of tines 40 are strong magnetic field sources. In an alternative embodiment devices 56 may include acoustic wave diaphragms to generate sonic wave patterns. These embodiments can be used to trigger the magnetic and acoustic fuses used in modern mines.

The embodiments described above are not intended to limit the scope of the invention. For instance, a steel cable matrix could be used (instead of a chain matrix) in an anti-sag plowing system used for farming. The shape of the digging-knives may be varied for different uses and soil conditions. Other flexible harrows may be used. Many variations are possible. The scope of the invention is only intended to be limited by the following claims.

CLAIMS

1. An anti-sag plowing system comprising:
at least one rigid digging-knife unit including a digging-knife portion having at least one digging-knife with a first length, and a bracket portion having a second length forming an obtuse angle with said digging-knife portion wherein;
said second length is longer than said first length, and;
towing means attached to said bracket portion at a towing location, and
pulling means attached to said bracket portion at a pulling location more distant from said digging-knife portion than said towing location.
2. The system of claim 1 wherein said towing means exerts a towing force on said bracket portion along a towing axis, and;

said pulling means exerts a pulling force on said bracket portion along a pulling axis, wherein;

said towing force is greater than said pulling force so that;

said towing force tows said digging-knife portion through a resistive medium that exerts a variable resistive force on said digging-knife portion with a component in the same direction as said pulling force.

3. The system of claim 2 wherein said bracket and said towing axis are parallel when said resistive force is less than a given value, and;

said bracket is rotated with respect to said towing axis when said resistive force is greater than said given value.

4. The system of claim 2 wherein said pulling means is connected to a source of drag on said resistive medium.

5. The system of claim 4 wherein said at least one digging-knife unit is a plurality of digging-knife units.

6. The system of claim 5 wherein said source of drag is a flexible harrow.

7. The system of claim 6 wherein said towing means and said pulling means are side chains.

8. The system of claim 7 wherein said harrow is covered with a pattern of chains to form a chain blanket.

9. The system of claim 7 wherein said side chains are connected to a rigid draw bar and said harrow.

10. The system of claim 9 wherein draw cables are connected to said draw bar on one end and to each other on their other end.

11. The system of claim 9 further comprising a first spreader bar connected to said harrow on the same side as said side chains, and a second spreader bar connected to said harrow on the opposite side as said side chains.

12. The system of claim 6 wherein said harrow has electrical devices mounted thereon which generate magnetic field or sonic waves.

13. A reversible plow system comprising a digging-knife unit with one set digging-knives pointed upwards on top of said digging-knife unit, and one set of digging-knives pointing downwards on the bottom of said digging-knife unit.

14. The plow system of claim 13 further comprising harrows connected to each side of said digging-knife unit wherein one harrow has tines pointing upwards, and the other harrow has tines pointing downwards.

15. A method of clearing mines comprising:

using one or more helicopters or ground vehicles with towlines to tow an anti-snag plowing system that includes;

at least one rigid digging-knife unit including a digging-knife portion having at least one digging-knife with a first length, and a bracket portion having a second length forming an obtuse angle with said digging-knife portion, wherein;

said second length is longer than said first length, and;

towing means attached to said bracket portion at a towing location, and pulling means attached to said bracket portion at a pulling location more distant from said digging-knife portion than said towing location, wherein;

said towing means is attached to said helicopter via said towline, and said pulling means is attached to drag force means

16. The method of claim 15 wherein said drag force means is a flexible harrow, and said towing and pulling means are chains, and; a pattern of chains lies on top of said harrow.

ABSTRACT OF THE DISCLOSURE

An anti-snag plowing system suitable for clearing mines in the Middle East is disclosed. Advantageously, the plowing system has also been found to be an efficient and effective soil conditioner, making it a useful farming tool as well. The plowing system comprises several digging-knife unit, or plows, and a harrow. Both are attached in tandem to a chain matrix, which is pulled with either a helicopter or tractor. The digging-knife units rotate if the digging-knives hit an immovable snag. The harrow is

covered with a chain blanket, and may have magnetic or sonic wave mine triggers if the system is used for clearing mines. A symmetrical embodiment is also disclosed.

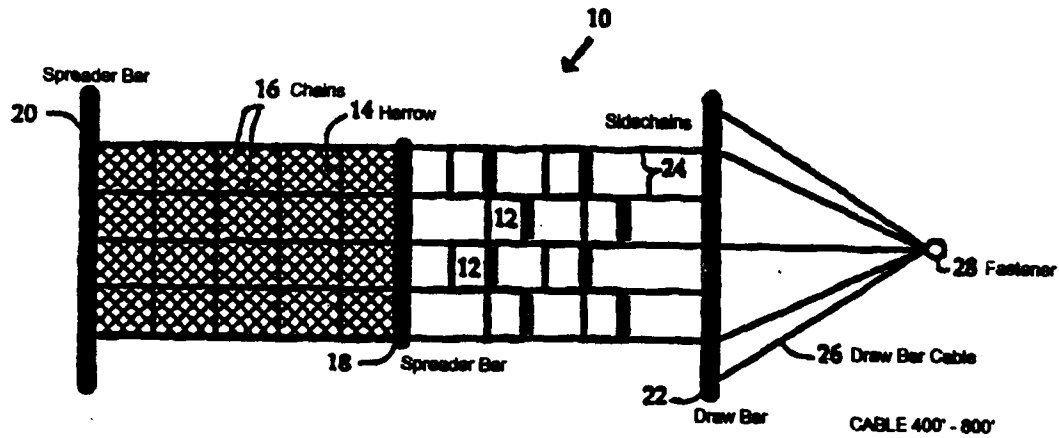


Figure 1.

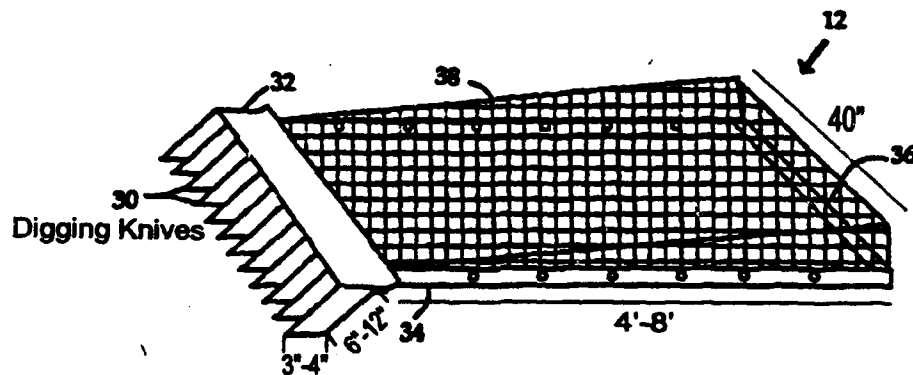


Figure 2.

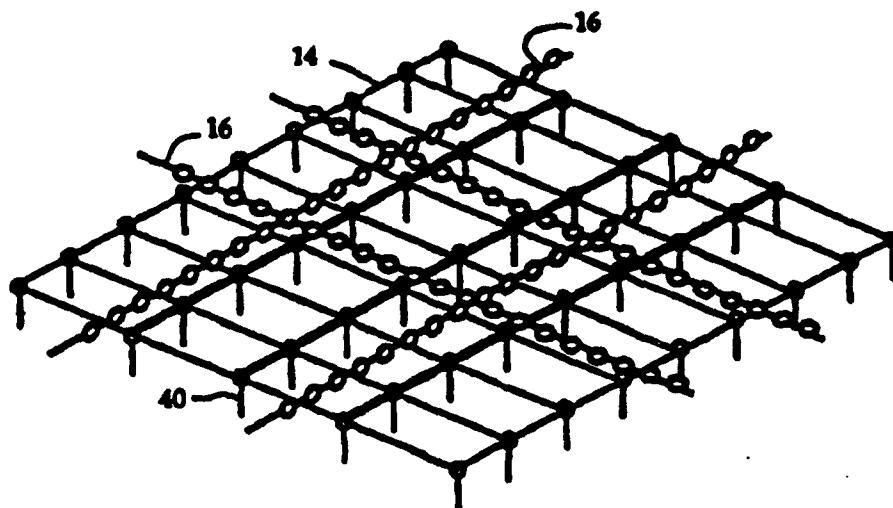


Figure 3.

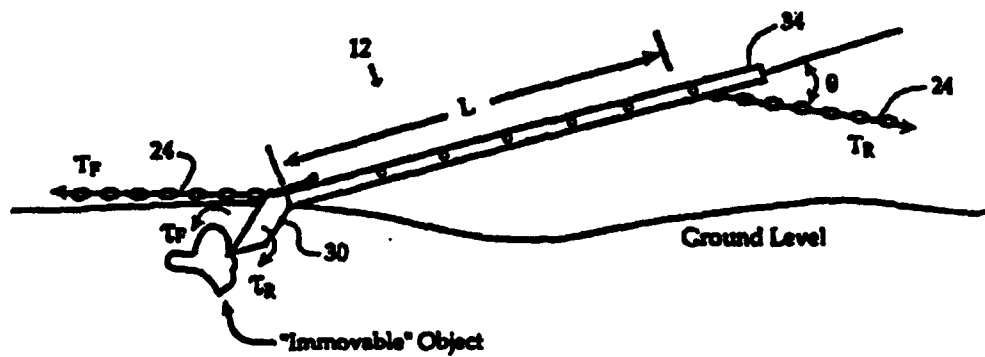


Figure 4.

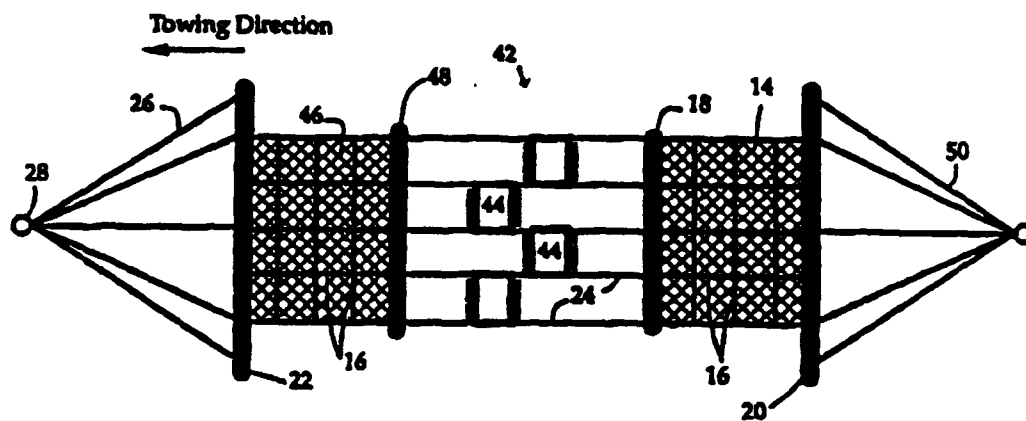


Figure 5.

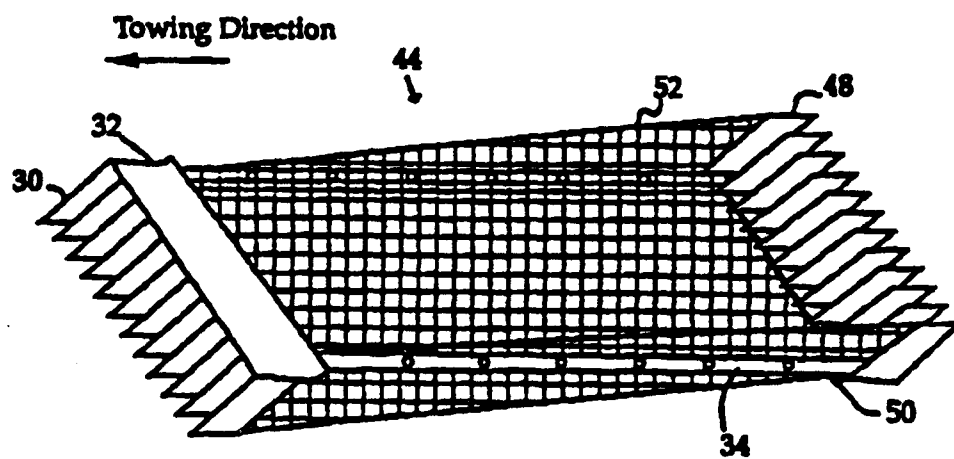


Figure 6.

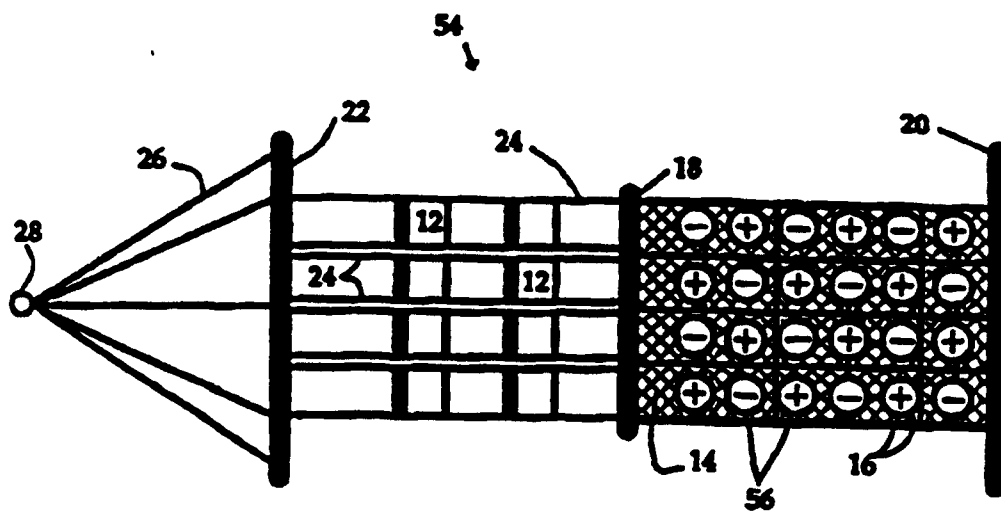


Figure 7.

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